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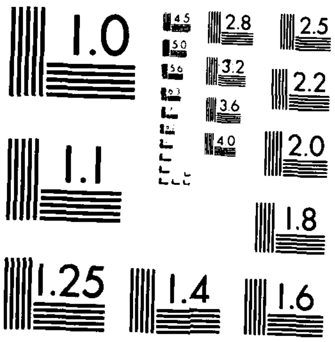
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CONCURRENT ENGINEERING: A NEW PARADIGM

BY

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USAWC CLASS OF 1991

U.S. ARMY WAR COLLEGE, CARLISLE BARRACKS, PA 17013-5050

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CONCURRENT ENGINEERING: A NEW PARADIGM

AN INDIVIDUAL STUDY PROJECT

by

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ABSTRACT

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Prior to the Mid-1950's, the U.S. policy for the acquisition of weapons systems was one based on quantitative superiority. We used that policy and our vast manufacturing capability to help win against the Axis powers. As we approached the 1960's the Defense Department implicitly de-emphasized quantitative superiority and stressed high technology "qualitative superiority" as the new policy. This project is a study of how the shift to a qualitative superiority policy has negatively impacted the U.S. weapons development process and how the implementation of a new engineering methodology can help to remedy the situation.

INTRODUCTION

Our victory in World War II was as a result of a combination of national will and a variety of other national strengths. One key feature of that collection of strengths was our ability to mobilize the material resources of this country and wage a war of attrition. The victory, in part, was won by overwhelming the Axis with our production might and shear quantity of weapons and logistical support. This emphasis on production was retained by the Department of Defense as a key element of national security until the mid-1950's. With adoption of the "qualitative superiority" policy, manufacturing as a key element of weapons system acquisition was implicitly de-emphasized. This lack of emphasis on manufacturing led to the breakdown of a development process that was well understood by U.S. industry at that time. Many colleagues who worked in industry during the years prior to the adoption of qualitative superiority in the 1950's and 60's, describe what is now called concurrent engineering, a familiar concept. In the days of quantitative superiority, where manufacturing and logistical process development were equally important to product development, everyone owned the overall development from concept to fielding.

The qualitative superiority strategy has served us well during the cold war years and can continue to provide force multipliers on future battlefields anywhere in the world, as witnessed in Iraq. Our current and future forces will have to deal with a full spectrum of threats including terrorism, subversion, insurgency, drug trafficking and low intensity warfare in third world countries that have the potential to be equally as lethal as Europe or the Mid-East. "A dramatically different security environment is emerging that is principally characterized by a diminished Soviet threat, reduced defense resources, and an increasingly complex world. These realities imply a reshaping of US security policy, strategy, force posture, and capabilities. The challenge is to reconcile enduring objectives and tasks with repositioned and restructured forces without foreclosing options for hedging against new or renewed threats." (1) In short, we must continue the policy of qualitative superiority, but can we afford it, or will what we can afford be sufficient to fulfill our national security needs in the 21st century?

A key issue related to our future national security strategy is the ability of our acquisition system to continue to provide the weapons that have allowed a qualitative superiority for all these years. Weapons system acquisition is one of the most complex and important decision processes

managed by the Federal Government. In a very real sense, the national security, our national economic competitiveness through technology development and the federal budget are impacted by the effectiveness and efficiency of this process. As stated in Department of Defense Directive 5000.1, Major and Non-Major Defense Acquisition Programs, the "policy of the Department of Defense is to assure that the DOD Acquisition System functions in a timely, efficient and effective manner to achieve the operational objectives of U.S. Armed Forces in support of national policies and objectives...."

We have built an extremely complex acquisition system over many years to accommodate the development and manufacture of the most sophisticated and technologically advanced weapons systems in the world. This acquisition system has become so complex and cumbersome as to be almost impervious to change. Attempts over the years to reform or streamline the acquisition process have had little more effect than that of a band-aid to a serious wound.

In light of the tremendous success we have enjoyed with the use of high-tech weapons in Operation Desert Storm, finding fault with the development system which brought us those weapons will be very difficult to understand unless we

look a few years down the budget path. After Desert Storm has ended and the Army is forced to continue down sizing, the vast amounts of money which forged our technological superiority will not be available. In short, we will not have the resources to continue to develop weapons systems in the same old way. Witness to this statement is the fact that in the next budget year the U.S. Army procurement account will be smaller than the U.S. Navy research and development account. In the out years R&D accounts may improve, however, we are still left with a very complex and wasteful development and acquisition system.

There is ample evidence that the methodology exists to solve many of the weapons acquisition problems, we simply need new vision. That new vision must be implemented from the top down in order not to become a limited fix when an entirely new and comprehensive approach is required. There is a new paradigm, it is called "Concurrent Engineering." Concurrent Engineering has also been called concurrent design by the Japanese, simultaneous engineering and a host of other names by different groups.

Concurrent engineering is being used very successfully by commercial industry in this country to close the

development and manufacturing gap with their international competitors who have been using concurrent engineering techniques for years. In fact, foreign manufacturers learned the concept of from us years ago and evolved it to its current state. "Concurrent engineering is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule and user requirements." (2)

The development of a product is a process which goes from the recognition of a need to the satisfaction of that need. This may be called the product delivery process and since it is a process, it may be managed and improved. There is a continuum of implementations of this process and the best embodiments are Concurrent Engineering. Concurrent engineering addresses all levels of complexity, from simple or single technology items to sophisticated or multiple technology systems; services to software to hardware. The Packard Commission found that virtually all DOD system products have a commercial analog. This is an important

point in that many of the prime U.S. examples of the successful implementation of concurrent engineering are in the commercial sector.

The reader must understand that concurrent engineering is not going to resolve Defense budgeting and program funding instabilities, Congressional micromanagement, or incompetent leadership. Nor will it provide for accurate and timely threat assessments. What concurrent engineering can do, from the time a weapons concept is being considered for development, is provide a framework for that development that is a completely inclusive process. From "cradle to grave" the weapon will be designed, developed, manufactured, fielded and supported as a single process mentality and at it's highest level, all players will have a conscious ownership of the process.

This paper will provide the reader with a synergistic view of where we have been with our development process, as it relates to moving a product from research to production, and where we should be going with that process in order to better allocate future scarce DOD resources against serious and competing national security alternatives. For the purpose of structure, the paper is organized around the classic military strategy technique of ENDS, WAYS and MEANS.

By definition, strategy is: "The art and science of employing the armed forces of a nation to secure the objectives of national policy by the application of force, or the threat of force." (3) The definition of strategy for the purposes of this paper will be: The art and science of utilizing the techniques and concepts of concurrent engineering to continue to produce state-of-the-art weapons of higher quality, lower cost, and shorter schedules that meet or exceed the requirements of the user. This strategy is divided into Ends, or objectives towards which one strives; Ways, or courses of action to attain an end; and Means, or instruments used in the courses of action.

ENDS

The ends we seek are clearly defined by DOD guidance, however, one could question whether the policy spelled out in DOD Directive 5000.1 is being realized in any meaningful way across the broad spectrum of weapons currently under development. We are rightly basking in the glow of our successes regarding advanced weaponry employed in Operation Desert Storm. But one must remember that those weapons systems were developed during a period when development resources were relatively unconstrained and were technically and logistically matured by shear force of dollars over long periods of time. (See figure 1) The question that naturally follows is, will we be able to provide equivalent technology to our troops in the future given the potential technical evolution of the threat and our diminishing resources? The answer to this question must be yes, however, we cannot accomplish that goal by developing weapons in the same old way.

Qualitative superiority of weapons systems over quantitative superiority has lead us to focus research and development on devices and features at the expense of processes. The shift to more high technology weapons should have signaled the need to develop parallel improvements in

manufacturing technologies and processes. "The focus on qualitative superiority has also led to more highly differentiated, sophisticated weapons (eg., B-2, ATF), which require omplex manufacturing processes to be developed and applied to progressively smaller production lots." (4)

Because of the sequential approach to weapons development currently used, the time available to develop and amortize the new manufacturing technologies is shortened and becomes almost cost prohibitive. (5) DOD consistently operates on the theory that industry has the facilities and capability to manufacture any product that can be designed. This theory is simply not the case, state-of-the-art technology requires state-of-the-art manufacturing processes and facilities for production which in most cases requires very expensive simultaneous development. "Historically, the Department of Defense has relied on the strength of American manufacturing. It was largely assumed that the suppliers possessed the know-how and the resources required to provide the fabrication facilities, in that standard processes used for commercial as well as military products were available. DOD research and development programs financed the development and design of products needed by the military,

but industry was expected to provide for the development of the wide range of technologies and facilities that are needed to create these new weapons." (6)

As the emphasis shifted from quantitative to qualitative superiority, the conceptual, demonstration and development phases of a new or updated weapons system focused almost entirely on the development of a product, not on manufacturing, deployment and maintenance. Only after the fact, or late in the development of a weapon system, were considerations made about how the system would be manufactured and supported. Cost considerations also fall into this same category. (7) The United States is still the world leader in innovation and invention and we continue to lead the world in technology development, but at what cost?

The developers of World War II weapons, such as the B-17 bomber, and the current state-of-the-art Patriot Missile, confronted the same dilemma: how to develop, field and support sophisticated military hardware using unproven technologies and a complex, bureaucratic development and acquisition system. In today's weapons systems defining the need, developing requirements and then developing and producing the system may take 12 to 14 years or more. (8) When the systems are finally delivered, they are frequently

out dated relative to the current technology available. "The only effective way to reduce the life cycle cost of a weapons system is to ensure that it is designed from the beginning with as much attention to operational costs (and operational readiness) as given to weapons system function. The biggest cost driver for initial procurement costs is change once production begins. Change can double the cost of subcontracted items." (9) Concurrent engineering, involves massing our development forces, including design, development, test, production and logistics, at the front end of the development, keeping them integrated throughout the development cycle; i.e., to do it right the first time so that changes are not required.

Studies, such as the one conducted by the U.S. Technology Assessment Team, show that seventy to eighty percent or more of the projected life cycle costs are built in at the planning and design stages. These same studies also show that up to eighty percent of the quality defects in a product are traceable to design flaws, not manufacturing. (10) From personal experience, industry executives believe that by the time a system has completed the design stage, as much as 85% of the projected life cycle costs may be built in and under our current sequential/serial development approach cannot be impacted easily. (See Fig. 2)

Commercial industry has begun to reverse this serial development process by implementing concurrent engineering while the DOD continues, with minor exceptions, the serial process. "The sequential and segmented style arose in an environment in which product development was not considered a process. Cloistered groups of specialists, looking inward within their own speciality emphasized isolated tasks that were amenable to their specialized skills. Concurrent engineering has evolved by thinking about the tasks as elements in an integrated process." (11)

The serial development process fostered an environment where the product was designed and then down stream considerations for quality, production capability and field support capability occurred. The fundamental problems with the serial development approach are now widely recognized in commercial industry. This approach is very often characterized as throwing the product over the wall. In other words, the design department completes its work and throws it over an invisible barrier to the fabrication department, who in turn throws their work over the same type barrier to the test and evaluation department and they in turn throw their work over the wall to the production department, etc. Between each barrier there is much

sub-optimization, gross loss of understanding of the real product, and late starts and delays waiting for the product or information to be thrown over the wall. (12)

In products developed by a substantially serial process, early design is dominated by performance and product function considerations. "Manufacturing considerations were brought in later, usually too late to affect the design in any meaningful way. DOD contractors are required to follow this serial approach. In designing military products, performance factors can be overwhelming unless other issues can be forcibly introduced. Achieving the desired performance can be extremely difficult in itself, whereas manufacturing or life-cycle considerations can require major design changes. From a technical and budgetary standpoint, it is usually impossible to make such changes late in the design process. Any changes adopted tend to be cosmetic at best, with the result that products cost too much to make, use and repair." (13)

The graphic below represents a comparison of sequential versus concurrent engineering. However, the differences between sequential and concurrent engineering are not that simple. In the sequential approach information flows are from left to right, in one direction as shown by the arrows.

In the concurrent approach, information flows are bidirectional and decisions are based on consideration of downstream as well as upstream inputs. (14)

Sequential Engineering

```
Requirement      Product Dev      Process Dev      Prototype
---------->      ---------->      ---------->      -------->
```

Concurrent Engineering

```
Requirement
<--------->
↑       Product Dev
↓       <--------->
        ↑       Process Dev
        ↓       <--------->
                ↑       Prototype
                ↓       <------->
```

The end we seek is embodied in the concept of concurrent engineering. It is a fundamentally different and a seemingly

common sense way of looking at how weapons systems are designed, engineered, manufactured and supported. "The idea is that people can do a better job if they cooperate to achieve a common goal. To implement this concept successfully the members of management, labor and the technical staff must develop a profoundly different insight, namely the process insight, into the nature of industrial activity. The process insight is the realization that all activities which transform a collection of inputs into a product satisfying a need are a single process. This process can be measured, managed and continually improved. The improvements must include both the breakthroughs associated with new inventions and the small improvements that result from everyday suggestions. For many products, even simple parts, the overall process will be broken down into more easily managed tasks, but the tasks are not viewed as ends in themselves. They are not optimized at the expense of the overall process. In the ideal form of concurrent engineering, the detailed design of the product is performed concurrently with the development of production capability, field support capability and quality." (15)

The principal findings of a recent Institute for Defense Analysis, Inc. study on concurrent engineering in the

commercial sector were that the benefits accrued to concurrent engineering included:

"- Improving the quality of designs which resulted in dramatic reductions of engineering change orders (greater than 50 percent) in early production.

- Product development cycle time reduced by as much as 40 to 60 percent through the concurrent, rather than sequential, design of product and process.

- Manufacturing costs reduced by as much as 30 to 40 percent by having multi-discipline teams integrate product and process designs.

- Scrap and rework reduced by as much as 75 percent through product and process design optimization.

- Collectively, the concurrent engineering disciplines that require the early consideration of a product's manufacturing and support process while shaping the user's requirements into a product's design were reported to result in a higher quality design." (16)

Concurrent engineering is not a concept to be used as a formula or recipe to solve problems. On the contrary, it is a mind-set, a view by <u>everyone</u> involved in the development of a weapon system that they are part of a continuous process and have ownership in the entire process.

WAYS

Our ability to continue to maintain a formidable combat capability into the next century depends largely on our ability to recognize and correct the weaknesses and complexities of our current acquisition systems as it applies to designing, manufacturing, fielding and supporting what we develop. Early in 1990, Mr. Donald J. Atwood, Deputy Secretary of Defense, had this to say about U.S. manufacturing: "America's deterrent strategy depends on a healthy industrial base - one that is efficient, technologically advanced and flexible enough to respond to any crisis. Unless we reverse the fortunes of American manufacturing, our national security may soon be in jeopardy." (17) The implementation of concurrent engineering, to impact the development process from the front end, is the paradigm change necessary to return the health and competitiveness of our national industrial and manufacturing bases and is also critical to maintaining the type of qualitatively superior combat capability we currently have and desire in the future.

During the time when DOD de-emphasized manufacturing, there was a parallel second order effect in commercial

industry perhaps from the shear weight of DOD dollars funding research and development on a national level. The commercial sector is reversing that trend out of a need to survive in an extremely competitive world market. Many of the U.S. commercial industry leaders emerging as viable world market competitors are doing so through the implementation of concurrent engineering. (18) The DOD has not reached the "survival mode" yet in terms of budget, but the current budget outlook reflects that possibility in the next few years.

Our tendency in the DOD during hard times is to cut or "salami slice" programs and many times without regard to the strategic view. The exercise requires having an extremely cumbersome bureaucracy apply a very blunt chopping tool to a complex set of established requirements, to fit an even more complex budget approved by a Congress that has a dimmer strategic view than anyone else in the process. In the commercial world, the real competitors do not cut products (programs) to balance budgets, they cut costs.

There are several key factors driving the development process and the $80 billion defense budget for weapons and research. Those factors include:

- Continuous performance improvements through technology push.
- High and increasing unit costs - reduced quantities
- Longer and longer development and production cycles (technology moving faster than development cycles).
- Problems in producing initial development designs (technologies not mature - lack of manufacturing process development)
- Poor field reliability
- lack of a realistic process for generating requirements and the lack of clarity in the definition of the requirements themselves impacts the entire weapons development process. (19)

Historically, DOD has done outstandingly well on the performance achievements of new systems, but has done far less well on cost, quality and speed of development and delivery. Recent DOD and commercial experience with new approaches to product development have demonstrated the potential to reduce cost, improve quality and schedules while at the same time achieving needed performance improvements. (20) Concurrent engineering provides for the design of a product and the processes to produce and support that product as a single integrated activity.

This approach provides the visibility and access to the interactions between product design and process design needed to achieve improvement in cost, quality and schedule. "For the last twenty years and in keeping with the decreased emphasis on manufacturing, both defense and civil research have focused primarily on device or product technology to the neglect of process innovation. This single-minded fixation on device technology and performance has an impact beyond that of slowing manufacturing process innovation: it accentuates the separation between identifying the threat, developing the requirements, design, manufacturing and support. This gives rise to increased problems of producibility and ultimately supportability because they are simply not considered to any extent in the requirements development and design phases, causing increased development time." (21)

The integration of product and process design is the common sense principle of concurrent engineering focusing on cost, quality and schedule. The basic idea is to apply concurrent engineering at every stage of development from the formulation of a concept forward, to guarantee the robustness of the design and the product during all downstream stages of design, production, fielding and support. Robustness is

accomplished by taking an integrated view of product and process design so the interactions and sensitivity to uncontrollable factors can be predicted and dealt with early (This is discussed in the Means chapter). Thus, downstream problems are preempted rather than detected and corrected.

By expending additional resources early in the acquisition process, concurrent engineering achieves long term benefits by greatly reducing schedules, unit and life-cycle costs, and by significantly increasing system quality. By simplifying the business and engineering process and by judicious application of formal methods and computer-aided engineering technology, however, the additional early expenditures can be reduced or eliminated. (See figure 3)

'Industry leaders in other countries believe that manufacturing is as important as product innovation or marketing in obtaining market share and have increasingly emphasized manufacturing design and process research and development. Estimates are that Japan devotes two-thirds of its R&D funds to improved processes and one third to improved products, while U.S. commercial industry devotes the opposite ratio, DOD is estimated to devote approximately 01% of its development budget to process improvement. This focus has

lead to a distinctive competitive advantage and dominance by foreign manufacturing over domestic industries in key areas." (22) It should be easy to understand, from this perspective, why an inordinate number of our weapons development programs falter as they transition to production.

From personal experience, industry executives believe that the Defense Industrial Base could produce just as efficiently if modern manufacturing innovation were emphasized by its primary customer, DOD. The current emphasis in DOD is on endless requirements documents in the form of specifications and directives. The result is bureaucratic prohibition of manufacturing process innovation by "stovepipe" organizations who control the specifications documents. Concurrent engineering drastically reduces the time to maturity by focusing due effort on manufacturing and support issues early on and throughout the development. (23) Reducing the time to maturity decreases the push or expectations of future technology improvements by focusing on less risky technology insertion. By reducing time to maturity, costs can be more accurately estimated and more closely adhered to. By slowing (not eliminating) technology push, performance expectations can be much more accurately established and achieved.

"DOD gives top priority to improvement in performance, capabilities, and lifetime of its weapons systems. Its recent approach to obtaining such improvements can be called "single feature improvement." Single features have become known as the "ilities" for producibility, reliability, maintainability, ect." (24) They are also frequently referred to as "stove-pipes" and "rice bowls." Sub-optimization through the sequential process of the "ilities" has been blamed for many delays and cost overruns. No one "ility" improves the total process or system readiness for production. The multi-discipline team, within the concept of concurrent engineering could be used to evolve the development system away from the barriers created by the "ilities." (25)

Implementation of concurrent engineering involves changes in management's approach in development process, tools and methods. As it currently exists, concurrent engineering is represented by three levels of accomplishment and implementation: basic, enhanced and world class. Basic concurrent engineering is simply good transfer of information between the design and development activities. Enhanced concurrent engineering uses one multi-discipline team to carry out the design and production/logistical capability development. World-class concurrent engineering is the ideal

form, where the detailed design of the product is performed concurrently with the development of production capability, logistical capability and quality. At every stage, an equivalent level of knowledge has been developed about the product and its associated processes. There are no U.S. manufacturers in the world class category and few in the enhanced category. Most companies in this country who have undertaken the effort to implement concurrent engineering are in the basic category and report that they realize that their undertaking is not short term. (26)

Improved management to accommodate concurrent engineering must feature emphasis on the concept from the top down, starting with the CEO/Secretary of Defense to the first line supervisor. Depending on the past management styles and practices, a change equivalent to a major cultural change may be required extending to the organizations business practices and contracting methods as well. Management must emphasize teamwork through the formation of multi-discipline teams. Team members should be given responsibility, authority and flexibility to communicate and make decisions and trade-offs that support the whole concept of concurrent engineering.

A recent DOD study of companies who had successfully implemented concurrent engineering found the following common characteristics:

- Upper management supported the initial change and continued to support its implementation.

- Changes were usually substitutions for previous practices, not just additional procedures.

- The members of the organization perceived a need to change. Usually there was a crisis to overcome. Often the motivation seemed to center around retaining or regaining market share.

- Companies formed teams for product development. Teams included representatives with different expertise, such as design, manufacturing, quality assurance, purchasing, marketing, field service and computer-aided design and support.

- Changes involved relaxing policies that inhibited design changes and providing greater authority and responsibility to members of design teams. Companies practicing concurrent engineering have become more

flexible in product design, in manufacturing and in support.

- Companies either started or continued an in-place program of education for employees at all levels.

- Employees developed an attitude of ownership toward the processes in which they were involved.

- Companies used pilot projects to identify problems that were associated with implementing new concurrent engineering techniques and to demonstrate their benefits.

- Companies made a commitment to continued improvement. None of the companies said that it was prepared to freeze the latest process as the ultimate solution to design and production." (27)

Not all of the companies implemented concurrent engineering in the same way or in the same time, and that is one of the very positive aspects of the concept. It is flexible and adaptable to almost any organization or situation.

Concurrent engineering amounts to more than just teamwork. It is very possible for one person to engineer a product and its processes concurrently. However, in the DOD world of large developments, that is not likely. It is more likely the product and each of its processes would be done by many individuals skilled in many different disciplines and working for many different companies. For concurrent engineering to work effectively, those in each discipline must work at the same time with sensitivity, interaction and consideration, and with the common, global goal of optimizing the product and all its related processes. The most common and most often used method to provide the needed interaction and consideration among the disciplines is to form multi-disciplined teams. The team has the responsibility of engineering the entire life cycle of the product from concept development through production and lifetime support. Multi-discipline team members continuously interact, trading off among the disciplines to optimize the overall project, not their own area or discipline. The formation of multi-discipline teams is the dominant method used by industry to implement concurrent engineering thus providing a vehicle for interaction and consideration. (28)

Concurrent engineering is characterized by a focus on the customer's requirements and priorities, a conviction that

quality is the result of improving a process and a philosophy that improvement of the process of design, production and support are never ending responsibilities of the entire enterprise. There are tools and methods available (discussed in the "Means" chapter) whereby user/customer needs can more readily be identified. From personal experience the requirements process in DOD does not always identify and ultimately represent the true user/customer.

The requirements for new weapons are often perceived as law and program managers will spend an enormous percentage of program money to achieve the final 5% of performance. The requirements documents, and to an equal degree oversight functions of Congress and various agencies, do not allow for cost/performance trade-offs. Further, the weapons requirements, as seen from the user perspective, are not fiscally constrained while the design is very often technically constrained. Other important requirements such as reliability and producibility are often ignored because the issues are difficult to conceptualize (early on), complex and either under funded or not funded at all. For example, unit production costs are rarely a critical military requirement yet if total yearly program dollars are constrained, then system numbers are constrained as are critical military requirements. Concurrent engineering was

not originally intended to play a part in requirements development, but the same features of the concept would apply and would contribute to integrating the requirements and development processes further.

At this point, it should be apparent, that there is no magic recipe for implementing the concurrent engineering concept. Very often the companies who implemented concurrent engineering were in a crisis situation and were desperately looking for a way to turn things around. Concurrent engineering is not a substitute for hard work and talented people; it is not a menu of tools to pick from when things are going badly, however, it does fit very neatly under the umbrella of Total Quality Management. Concurrent engineering is very compatible with systems engineering, in fact would not work well without it. "Concurrent engineering is not the arbitrary elimination of a phase of the existing sequential feed-forward engineering process. Concurrent engineering does not eliminate any engineering function. In concurrent engineering, all downstream processes are co-designed toward an all-encompassing, cost-effective optimum design." (29) The Army acquisition system and development programs are headed for hard times budget wise. We should not wait until we are in crisis before making the changes that will lead to a concurrent engineering approach within DOD.

The implementation of concurrent engineering methodology could begin in DOD weapons development programs by simply allowing and/or encouraging selected programs/contractors to use concurrent engineering concepts without fear of penalty. The Institute for Defense Analysis report on concurrent engineering indicates that many companies in the private sector are eager to formally implement this method with DOD blessing. In this early phase, DOD will have to insure that government acquisition personnel recognize and understand concurrent engineering well enough to write requirements and serve on source selection boards.

After the implementation of concurrent engineering and the effort begins to broaden, reform in the acquisition system will be accomplished more easily. At some future level of government and industry experience and expertise, we may be able to seriously transition to full implementation of the concept thereby eliminating barriers, stove-pipes, rice-bowls and the 'ilities' that so confound our current system.

MEANS

The means of correcting the problems pointed out in the previous chapters involve the intelligent and pervasive implementation of concurrent engineering and the vast array of tools available to do the job. The tools vary from computer aided design and engineering packages to vast computer networks for the purpose of keeping integrated teams informed and coordinated; from simple statistical process control procedures to complex procedures for identifying the needs and desires of the customer/user. This chapter will list and explain briefly some of these tools and how they apply to the scheme of concurrent engineering. This section is not oriented toward defining formal engineering methods or in any way identifying the concept as a methodology that can be used like a simple formula to solve problems.

Concurrent engineering is basically a mind-set for integrating complex activities, however it manifests itself in the form of usable and applicable tools and methods. The following is a selected list of the types of tools and methods currently being used by industry implementors of the concept:

- Multi-Discipline Teams. Multi-discipline teams consist of functional area experts who are selected by upper level management and represent different areas of a product's life-cycle. These functional area experts are the foundation necessary to concurrently engineer both the product and the downstream processes for design, development, manufacturing, fielding and support. When these teams are brought together early in the design stage, the result has been that the product is developed in a shorter time, at less cost and very often with higher quality. (30) Multi-discipline teams in the government sector would begin the process of eliminating "stove-piping" and hopefully move the bureaucracy toward incorporating the "ilities" into a multi-discipline team process.

- Process Perspective. This a management tool or method in which the entire organization adopts a universal process perspective and any product development is seen as a single continuous process from concept to fielding and support. The concept involves the management and optimization of the product under development as a single process, not as individual features to be sub-optimized at the expense of the whole. (31)

- Quality Function Deployment. Trade-offs made in the process of universally optimizing a product during

development should be based on the best information available from the customer. The complexity of DOD weapons systems development requires the exchange of very large amounts of very accurate information about the product from the user perspective and there is a serious need for a method to track those important relationships. Quality Function Deployment (QFD) uses the multi-discipline team approach to creatively brainstorm customer demands and design parameters and their correlation is ranked and normalized. Such data is collected from concurrent engineering participants of all disciplines. Matrices are used a' a visual means of recording the information ari 'orrelating it. For example, customer demands are often displayed in the rows of the matrix and other parameters are listed in the columns. Entries where rows and columns intersect indicate how parameters correlate. The application of QFD in concurrent engineering brings a more scientific approach to the collection and evaluation of information on which multi-disipline teams can make trade-off decisions. (32)

- Statistical Process control. (SPC) When dealing with pure engineering processes (eg.-design/manufacturing processes), as opposed to the management or methodology processes mentioned above, one must be able to evaluate alternatives and make trade-offs among product and various process designs, and engineers must have quantitative

understanding of the stability of important parameters. It is necessary to understand the variability of a process in the presence of uncontrolled 'noise' and to know the effect of changing controlled parameters on that variability. Statistical process control is one of the most widely used tools for determining whether observed variation is the result of normal fluctuation of a controlled process or the result of some special, uncontrolled cause. The 'Means' addressed in this chapter are generally limited to management and methodology concepts or other than pure engineering methods. However, SPC is of such importance to the concurrent engineering concept and so widely used in industry that it should not be excluded from this list. (33)

- Robust Design. An idea significantly enhanced by a Japanese engineer, Genichi Taguchi, robust product design encompasses the idea that producing products which are merely within specification is not adequate. Robust product design starts with the concept that quality loss can be minimized if some characteristics of the product have an ideal target value. The manufacturer must recognize that quality loss increases geometrically as the real-time production run value varies from the target value. Using this concept, it no longer suffices to produce items that are merely within specification. (34)

- Integrating Technologies. Concurrent engineering is best facilitated by team members from different disciplines having access to each other and each others work. This creates some technological problems because concurrent engineering typically teams up specialists who address designs using their own methods, representations, and manual and automated tools. Given the trend toward the use of automation for synthesis, analysis and capture of designs, multi-discipline teams require tools and representations that work together easily. There are many engineering design packages that, if standardized, would work well in this role. The Xerox Corporation is experimenting with what is called a cooperative design laboratory in which the multi-discipline team can sit in one room and collaborate on virtually any development through networked computers and shared audio visual aids. DOD initiatives such as the Computer-aided Acquisition and Logistics Support (CALS) and the Product Data Exchange Specification (PDES) offer great promise in both the integrating framework and description languages currently needed to support concurrent engineering. (35)

- Customer Involvement and Supplier Involvement. In the commercial world, the customer is easily recognized. In the case of the DOD, the customer is not always easy to determine because the identity and role of customer and user get confused and misinterpreted. One of

the basics of concurrent engineering is to recognize the voice of the customer, which automatically requires that the customer be readily identifiable. To an equal degree, the multi-layered supplier base is crucial to the success of any development effort and especially within the concept of concurrent engineering. Bringing suppliers into the concurrent engineering process means interacting with the multi-discipline team and making trade-offs to achieve the optimum overall product and process.

As stated, the methods listed in this chapter are by no means the only tools and methods suitable for use under the concurrent engineering umbrella. Each company and project management office is different environmentally and we must be adaptable enough to use what ever tools are necessary and applicable to the development and the environment.

CONCLUSION

"The U.S. industrial base must be prepared to respond to a broad range of contingencies that may emerge in the future. In the past, we have tended to develop defense production capabilities primarily via individual weapon system programs. In the future, we will need to rely increasingly on the technological leadership that is available in the commercial sectors and take into account the increasing international character of emerging product and process technologies." (36)

Concurrent engineering does not represent a completely new acquisition system. It does, however, provide the framework for establishing new "Ends" in the development process by shortening development times for high technology weapons systems, at lower cost and with higher quality. In a time of gross reductions in the defense budget, the potential ends provided by the implementation of concurrent engineering are too significant and appealing to ignore. As pointed out in a recent DOD study, "Companies that have implemented concurrent engineering report that they are producing higher quality products at lower cost and in less time than they were able to previously....Significant differences exist between the commercial market place and the DOD domain. Despite these differences, case studies of the implementation

of concurrent engineering by several defense contractors suggest that concurrent engineering can be successfully applied in the DOD environment." (37)

"It is now generally recognized that a strong manufacturing base is essential to leading-edge industries as well as to mature industries. Moreover, mastery of the manufacturing process is increasingly viewed as an essential part of the technical competence that is necessary to advance existing technologies and create new ones." (38) From the author's personal experience, commercial industry recognizes the gravity of this quote and is consistently moving away from DOD business and methods. As many of them adopt concurrent engineering concepts and practices, they are less compatible with the way in which DOD dictates <u>how</u> something should be built and not <u>what</u> it wants built. The companies remaining in the DOD business arena are beginning to opt for concurrent engineering methods and concepts as a survival strategy. However, they continue to maintain their mirror image of DOD organization in terms of the "ilities" even after those departments are no longer required. DOD can simply allow concurrent engineering to evolve in the defense industry by doing nothing. However, the much more productive method or "Ways" of accomplishing this transition is be more proactive on the DOD side. By providing senior level

leadership, training of the acquisition bureaucracy and evolving change in DOD organization and structure, concurrent engineering could be implemented in a much shorter time than by simply letting the market drive industry contractors to it because they need it to survive. Concurrent engineering fits very easily under the umbrella of Total Quality Management; TQM requires continuous process improvement, concurrent engineering manifests this concept in its process mentality and the acceptance by everyone involved of ownership in the total process.

"The United States continues to be the world's leader in the development of new technology; however, it is no longer the leader in many areas of technology application, nor can the U.S. be self-sufficient in the production of all items. The U.S. must nevertheless ensure that it does not become vulnerable to a potential disruption in supplies for materiel vital to our national security. The United States must be able to identify and deal with such vulnerabilities and develop **assured access** to products and technologies that are required to support our military forces in the next century. As critical product and process technologies are identified, the Department of Defense must work together with industry and academia to ensure continued U.S. leadership in these important areas." (39)

SYSTEM	IIIA DECISION	III DECISION	IIIA DEL	III DEL	R & M MATURITY
Project A	Month 0	Month 12	Month 24	Month 40	Month 79
Project B	Month 0	Month 27	Month 37	Month 57	Month 72
Project C	Month 0	Month 24	Month 15	Month 36	Month 47
Project D	Month 0	Month 35	Month 15	Month 43	Month 62
Project E	Month 0	Month 67	-	-	Month 93
Project F	Month 0	Month 34	Month 22	Month 55	Month 59
Project G	Month 0	-	Month 22	Month 58	Month 76

R & M Maturation in the Acquisition Process

Figure 1

Source: OASD(P&L)

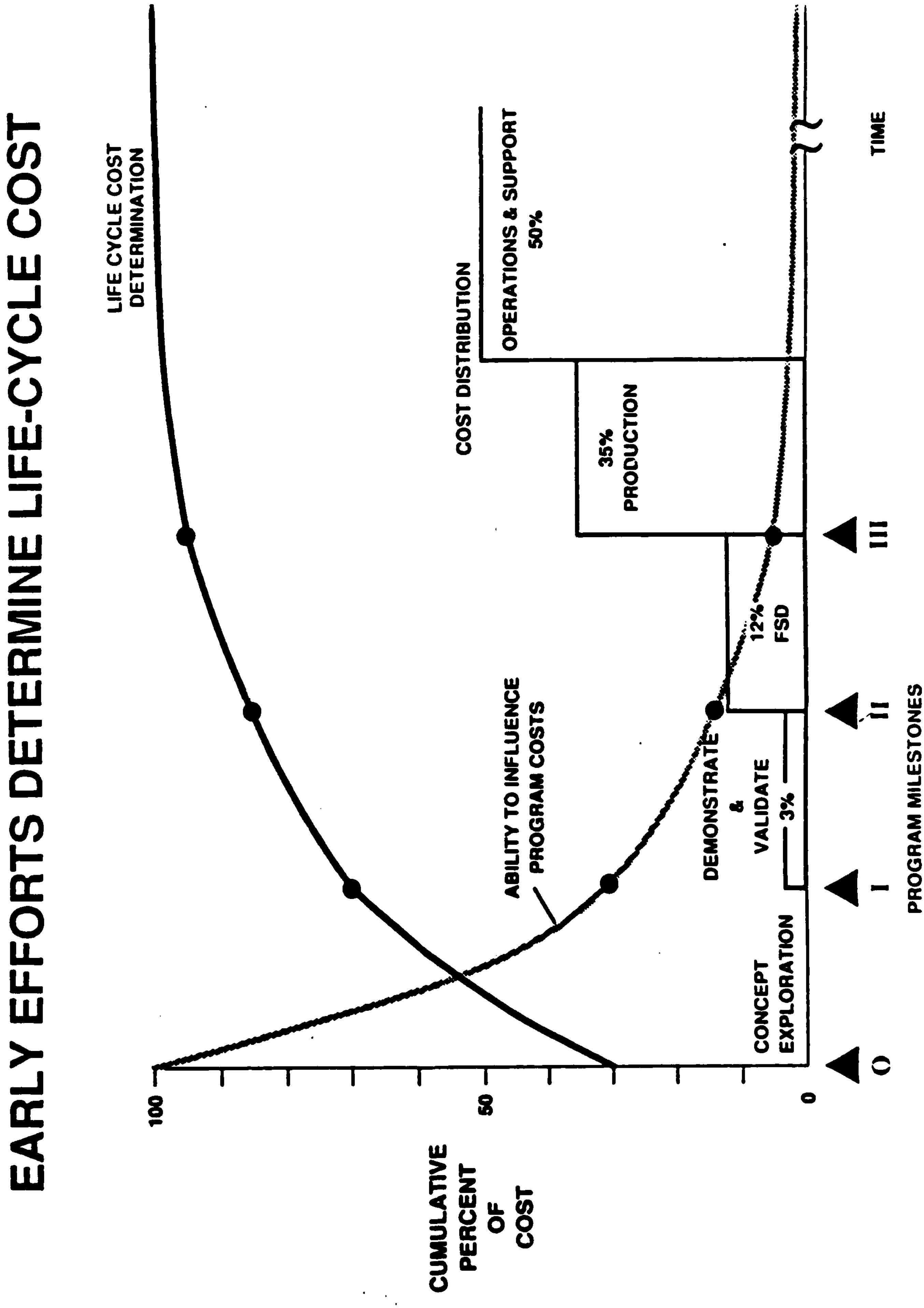

Figure 2

Source: OASD(P&L)

Case Study	Cost	Schedule	Quality
McDonnell Douglas	60% savings on bid for reactor and missile projects.	Significant savings (reduction from 45 weeks to 8 hours) in one phase of high-speed vehicle preliminary design; 18 month saving on TAV-8B design.	Scrap reduced 58%, rework cost reduced 29%, and nonconformances reduced 38%; weld defects per unit decreased 70%; 68% fewer changes on reactor; 68% fewer drawing changes on TAV-8B.
Boeing Ballistic Systems Division	Reduced labor rates by $28/hour; savings 30% below bid.	Part and materials lead-time reduced by 30%; one part of design analysis reduced by over 90%.	Floor inspection ratio decreased by over 2/3; material shortages reduced from 12% to 0; 99% defect-free operation.
AT&T	Cost of repair for new circuit pack production cut at least 40%.	Total process time reduced to 46% of baseline for 5ESS.	Defects reduced by 30% to 87%.
Deere & Company	30% actual savings in development cost for construction equipment.	60% savings in development time.	Number of inspectors reduced by 2/3.
Hewlett-Packard Instrument Division	Manufacturing costs reduced 42%.	Reduced development cycle time 35%.	Product field failure rate reduced 60%. Scrap and rework reduced 75%.
IBM	Product direct assembly labor hours reduced 45%.	Significant reduction in length of PMT design cycle. 40% reduction in electronic design cycle.	Fewer engineering changes. Guaranteed producibility and testability.

Cost, Schedule, and Quality Benefits.

Figure 3

Source: DOD/IDA Report R-338

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